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April 14, 2004

MAIL STOP PATENT APPLICATION  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

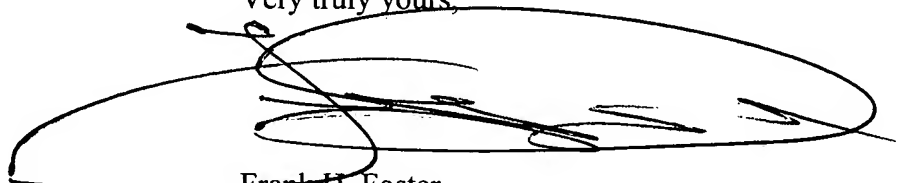
Re: Disclosure Document  
Title of Invention: Temperature Control For Free-Piston Cryocooler With Gas Bearing  
Our File No.: SUN 6100

Honorable Sir:

The subject matter of the patent application enclosed herewith is related to the contents of the below-identified Disclosure Document, and it is requested that the Disclosure Document be retained by the U.S. Patent and Trademark Office in the file for the enclosed patent application.

Disclosure Document No.: 509928  
Filed: April 15, 2002  
For: Hybrid Temperature Control For Free-Piston Cryocooler With Gas Bearings  
Inventors: Douglas Keiter and Ezekiel Holliday

Very truly yours,

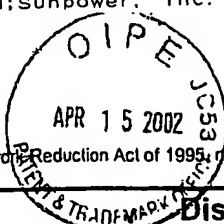


Frank H. Foster

FHF/db

Enclosures: Disclosure Document

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FOR FRANK FOSTER

DISCLOSURE DOCUMENT NO.



509928

RETAINED FOR 2 YEARS

THIS IS NOT A PATENT APPLICATION

PTO-1652(8/99)

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# Disclosure Document Deposit Request

Mail to:

Box DD  
Assistant Commissioner for Patents  
Washington, DC 20231

Inventor(s): Douglas Keiter and Ezekiel Holliday

Title of Invention: Hybrid Temperature Control for Free-Piston Cryocooler with Gas Bearings (SUN 6100)

Enclosed is a disclosure of the above-titled invention consisting of 2 sheets of description and drawing. A check or money order in the amount of \$10.00 is enclosed to cover the fee (37 CFR 1.21(c)).

The undersigned, being a named inventor of the disclosed invention, requests that the enclosed papers be accepted under the Disclosure Document Program, and that they be preserved for a period of two years.

Douglas E Keiter  
Signature of Inventor

Douglas Keiter  
Typed of printed name

3/28/02  
Date

Ezekiel Holliday  
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## NOTICE OF INVENTORS

It should be clearly understood that a Disclosure Document is not a patent application, nor will its receipt date in any way become the effective filing date of a later filed patent application. A Disclosure Document may be relied upon only as evidence of conception of an invention and a patent application should be diligently filed if patent protection is desired.

Your Disclosure Document will be retained for two years after the date it was received by the United States Patent and Trademark Office (USPTO) and will be destroyed thereafter unless it is referred to in a related patent application filed within the two-year period. The Disclosure Document may be referred to by way of a letter of transmittal in a new patent application or by a separate letter filed in a pending application. Unless it is desired to have the USPTO retain the Disclosure Document beyond the two-year period, it is not required that it be referred to in the patent application.

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If you are not familiar with what is considered to be "diligence in completing the invention" or "reduction to practice" under the patent law or if you have other questions about patent matters, you are advised to consult with an attorney or agent registered to practice before the USPTO. The publication, *Attorneys and Agents Registered to Practice Before the United States Patent and Trademark Office*, is available from the Superintendent of Documents, Washington, DC 20402. Patent attorneys and agents are also listed in the telephone directory of most major cities. Also, many large cities have associations of patent attorneys which may be consulted.

You are also reminded that any public use or sale in the United States or publication of your invention anywhere in the world more than one year prior to the filing of a patent application on that invention will prohibit the granting of a patent on it.

Disclosures of inventions which have been understood and witnessed by persons and/or notarized are other examples of evidence which may also be used to establish priority.

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Burden Hour Statement: This collection of information is used by the public to file (and by the USPTO to process) Disclosure Document Deposit Requests. Confidentiality is governed by 35 USC 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed Disclosure Document Deposit Request to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and

Sunpower, Inc.

Invention Disclosure Form

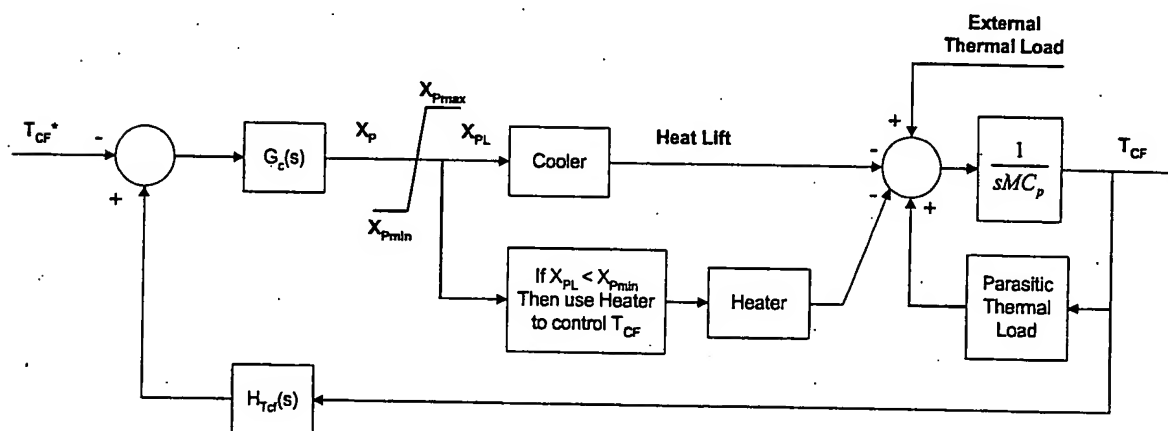
Sheet 2 of 2

Description of invention (include both description and sketches or drawings as appropriate):

### Hybrid Temperature Control for Free-Piston Cryocooler with Gas Bearings

modulate the power applied to a resistance heater to control cold end temperature. If the thermal load changes and the heater power is reduced to zero, then the control will switch back to piston stroke modulation to maintain the desired cold end temperature. Some logic and hysteresis will be added in the final embodiment to prevent oscillations at the crossover between control methods. The advantage of this control method is it provides the capability to use a single cryocooler in a range of thermal load applications while maximizing the efficiency and maintaining the functionality of the gas bearings in each application.

### Cryocooler Hybrid Temperature Control Block Diagram



Sunpower, Inc.  
March 20, 2002

Invention Disclosure FormSheet 1 of 2

Description of invention (include both description and sketches or drawings as appropriate):

**Hybrid Temperature Control for Free-Piston Cryocooler with Gas Bearings**

One method of controlling the cold end temperature of a Free Piston (Stirling or Pulse-Tube) Cryocooler is to modulate the stroke of the piston. Increasing the piston stroke will increase the cooling power available while decreasing the piston stroke will decrease the cooling power. In a Free Piston Cryocooler that uses gas bearings to prevent contact between the piston and the cylinder, or between the displacer and the cylinder, or between the displacer rod and the piston, a minimum piston amplitude is required to maintain enough pressure in the gas bearing system to prevent contact. This constraint imposes a limit on the minimum cooling power that the cryocooler can be modulated down to. If this minimum limit is greater than the actual cooling power needed by the thermal load, then the cold end temperature will not be maintained to the desired value.

Another method for controlling cold end temperature of a Free Piston (Stirling or Pulse-Tube) Cryocooler is to run the cooler at a constant piston amplitude, resulting in a constant cooling power at a given temperature. A resistance heater is then used to control the cold end temperature to the desired setpoint. The drawback to this method is that the input power to the cooler is constant, independent of the thermal load on the cold finger.

We propose a method that combines piston modulation with a resistance heater. Piston modulation would be used during the rampdown stage of the cooler, resulting in the maximum cooldown rate. Around the setpoint temperature, piston modulation would also be used unless the piston stroke was reduced to the minimum value that would insure proper function of the gas bearings. At this point, the control would hold the piston stroke to the minimum amplitude and

Invented by: \_\_\_\_\_ Date \_\_\_\_\_  
(Print name: Doug Keiter)

Witnessed and Understood by:

Invented by: \_\_\_\_\_ Date \_\_\_\_\_  
(Print name: Ezekiel Holliday)

1. \_\_\_\_\_  
signature, date

Invented by: \_\_\_\_\_ Date \_\_\_\_\_  
(Print name: \_\_\_\_\_)

2. \_\_\_\_\_  
signature, date

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For Patent Committee review: \_\_\_\_\_ Date of review: \_\_\_\_\_

- A. File for patent immediately \_\_\_\_\_
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